3D Analyst – Working with Terrain Datasets

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Content

- Overview
- Terrain dataset implementation
- Terrain dataset analysis
- Demonstration
- Suggestions
- Resources
Terrain Dataset

• A Terrain is a multi-resolution surface created from measurements stored in feature classes

• Typical applications:
  - Topographic mapping
  - Bathymetric mapping

• Typical data sources:
  - Photogrammetric data
  - Lidar
  - Sonar
Motivating Forces

- **Scalability**
  - Large collections of mass point data (e.g. LIDAR) have been a problem

- **Data integration**
  - Need surface to live with source data

- **Data management**
  - Database tools
  - Editing/update
  - Multi-user
Limitations to Overcome

• TINs have an effective limit of 20 million points
  - Based on 2GB per process limit of Win32
  - It’s recommended not to go over 3-5 million

• Updating TINs relative to edits of source measurement data is difficult
  - They are disconnected
  - Easiest thing to do is rebuild from scratch

• TINs only support Workstation Arc/Info projections

• Rasters are derivative
  - Difficult to update without rebuilding from source data
Need for Maintaining Topographic Baseline

• Many organizations are charged with keeping accurate and up to date topographic/bathymetric surfaces
  - Construction projects/permitting
  - Hydrologic/hydraulic modeling
  - Navigation

• Terrains offer database oriented solution for managing source data from which these surfaces are derived
What are Terrain Datasets?

- Terrain datasets live inside feature datasets within the geodatabase
- Identify which feature classes participate and how they contribute
- Rules specify how features are used to define a surface
Multi-Resolution Surface Model

Points and Breaklines

Terrain Pyramids

Thinned Point Set

Full Resolution

Multi-resolution terrain dataset (TIN structure)
Implementation – Levels of Detail

- TIN surface generated on-the-fly for given area of interest and level of detail
- Supports point, multipoint, polyline, and polygon based features
- Seamless
- Fast
- Scalable
Implementation - Tiling

- Spatial coherence and *tiling* (point clustering)
- Z tolerance and *vertical indexing*
- Measurement update and *dirty-areas*
- Localized processing
Implementation - Tiling

- Data is structured, internally, into tiles
- Spatially coherent parts
- Each tile contains a manageable amount of data
- Facilitates processing large amounts of data
Tile System Definition

- Defined by nominal point spacing and coordinate system
  - Point spacing controls tile size
  - Coordinate system defines origin and extent
- Terrain maintains properties that define tile system
  - Tile boundaries are not stored
  - Mathematically derived on-demand
Preventing/Reducing Tile Artifacts

• Problem associated with generic tile based processing
  - Interpolation neighborhoods are incomplete around tile boundaries
  - Artifacts when merging results of interpolation for multiple tiles

• Terrains address this issue automatically
  - Overlapped tiles provide a solution
  - Since neighborhoods are well defined around neat line boundaries tile derivatives merge seamlessly
Preventing/Reducing Tile Artifacts

• Systems that only use overlapped tiles can still have problem with incomplete or empty tiles
  - Occur over water bodies, obscured areas

• Terrain handles these problematic tiles automatically by identifying and flagging them as composite tiles
  - Include references to nearest points in surrounding tiles
  - Complete surface definition for area represented by tile
Composite Tiles

Tile in center is void of samples but references those in neighboring tiles. Triangulation of those points covers the tile.
Vector Based Pyramids

- Similar to raster pyramids in concept, but comprised of source measurements
- Point thinning
  - Heavy thinning for coarse levels
  - Lighter thinning for more detailed levels
  - No thinning at full resolution
- User defined scale threshold associated with each level
- For analysis as well as display
- Two pyramiding techniques: Z Tolerance or Window Size
Z Tolerance Pyramid

- TIN based decimation
- Generalized surface, for each pyramid level, within user defined vertical accuracy of full resolution surface
- Appropriate for bare earth data
- Should not be used with 1st return lidar surfaces (i.e., buildings and vegetation)
### Z Tolerance Pyramid

<table>
<thead>
<tr>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><img src="image5.png" alt="Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Levels of Detail</th>
<th>Z-Tolerance</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1:1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2500</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>10,000</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>50,000</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>100,000</td>
</tr>
</tbody>
</table>

The distance between the lower resolution surfaces and the full resolution surface will not exceed a given Z-tolerance.
Window Size Pyramid

- Simple binning or block filter
- Space partitioned into squares and one or two points selected for each square
- Selection criteria:
  - Min z, max z, min and max z, closest to mean z
- Effective for all data types
- Should be used with 1st return lidar
# Window Size Pyramid

<table>
<thead>
<tr>
<th>Level</th>
<th>Window Size</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1:1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2500</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5,000</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>10,000</td>
</tr>
</tbody>
</table>
Point Clustering

- One database row per point is too expensive
- Instead, points belonging to same tile and pyramid level are grouped into *multipoints*
- A multipoint is stored as an individual shape occupying one database row
- Reads and writes become more efficient
- Storage cost is reduced
- Only measurements are stored, TINs built on-the-fly
Point Clustering

• Many points are combined into a shape called a multipoint that is stored using one database row.
Input Data Formats - LAS

- LAS files are industry standard binary format for lidar
- Loaded using LAS to Multipoint tool

Benefits
- Avoids pitfall associated with ASCII format points
- Extent, point count, and spatial reference in header

Drawbacks
- Built in metadata is lacking in some areas
  - Can’t always tell how ‘raw’ the data is
  - Classification codes are not described
Input Data Formats - ASCII

• **XYZ, XYZI**
  - 3D points
  - Loaded using ASCII3DToFeatureClass GP tool

• **GENERATE**
  - 3D points, lines, polygons
  - Loaded using ASCII3DToFeatureClass GP tool
Handling Lidar (LAS) Attributes

- Per point attributes (e.g. return number, class code) optionally stored in BLOBs
- A separate BLOB field is used for each attribute
- Array of values with one-to-one correspondence with a set of grouped points is stored with points in same database row
Editing

• Updates accomplished through edits to source measurements
  - Coarse grained area operators to append, remove, replace mass points
  - Standard/custom edit tools (e.g. ArcEditor) used to modify polylines, polygons, spot heights
  - Terrain rebuild based on dirty-areas

• Support for versioning in SDE
Terrain Wizard

Choose terrain characteristics.

Select the Feature Class characteristics.

Choose the options for a feature class.

New Terrain Wizard steps:
1. Enter a name for your terrain dataset.
2. Select the feature class and pyramid levels.
3. Choose the resolution bounds and pyramid type.
4. Set the window size and point selection method.
5. Determine the secondary thinning method and threshold.

Terrain Pyramid Levels:
- No:
- 1
- 2
- 3
- 4
- 5

Resolution Bounds:
- Preserve Embedded Fields

New Terrain Wizard options:
- Z Tolerance
- Window Size
- Secondary thinning method
- Secondary thinning threshold

< Back  Next >  Cancel
Terrain Dataset Layer
Interactive Surface Analysis

- Interactive surface tools

3D Analyst toolbar in ArcMap
Geoprocessing Analysis

- Geoprocessing with Terrain Datasets
  - Terrain Management toolset
    - Creation
    - Modification
  - Data conversion toolset
    - Data loading
    - Surface conversions
  - Terrain and TIN Surface toolset
    - Analysis conducted directly on terrains
Analysis Capabilities for Terrain Datasets

- QA/QC lidar data
- DEM / DSM creation
- Slope
- Aspect
- Contours
- Surface differencing
- Intensity image generation
- Estimating Forest Canopy
- Data area delineation
- Thinning / reducing noise
- Spot interpolation
- Profiling
Working with Terrain Datasets

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Terrain Dataset Workflow

Data Conversion

- LIDAR post processed data: Points
- SONAR post processed data: Points
- Photogrammetric data: Points & Lines

Product Generation

- Proprietary or de-facto standard formats

Surface Integration

- Pyramid
- TIN surfaces

ArcGIS Terrain Dataset

- Contours
- Points
- Breaklines
- DEM
- TIN
Common Analysis: Creating Raster DEMs and DSMs

Digital Elevation Model

Bare earth surface made using only ground hits.

Digital Surface Model

Includes ground, trees, and buildings made using first returns.
Mapping and Visualization - ArcMap

- Displayed as a TIN
- Symbology same as TIN
- Resolution changes depending on zoom level
Mapping and Visualization – ArcGlobe / ArcScene

- Terrain datasets can be displayed as either elevation or draped layers in ArcGlobe.
- Terrain datasets are not directly supported in ArcScene.
Converting TINs to Terrain datasets

• First, look to see if the source feature data used to make a TIN is available and use it to make a terrain.

• Only if the source feature data is not available:
  - Decompose a TIN to features with GP tools
  - Make the terrain from the features
Resource – Help System

What is a terrain dataset?

A terrain dataset is a multiresolution, TIN-based surface built from measurements stored as features in a geodatabase. They are typically made from lidar, sonar, and photogrammetric sources. Terrains reside in the geodatabase, inside feature datasets with the features used to construct them.

Terrains have participating feature classes and rules, similar to topologies. Common feature classes that act as data sources for terrains include the following:
-\[\text{Terrain} \]
-\[\text{Point} \]
-\[\text{Line} \]
-\[\text{Surface} \]
-\[\text{Analysis} \]
-\[\text{Network} \]
-\[\text{Table} \]

The terrain dataset's rules control how features are used to define a surface. For example, a feature class containing edges of pavement lines for roads could participate with the rule that its features be used as hard breaklines. This will have the desired effect of creating linear discontinuities in the surface.

Features also indicate how a feature class participates through a range of scales. Some of convenient features are:

-\[\text{Landcover} \]
-\[\text{Building} \]
-\[\text{Lake_front} \]
-\[\text{Lake_Parks} \]
-\[\text{Sub_Area} \]
Exercise 8: Creating and using a terrain dataset

A terrain dataset is a multiresolution TIN-based surface derived from measurements stored in one or more feature classes in a geodatabase.

In this exercise, you will use preprocessing tools to load surface data into a geodatabase, construct a terrain dataset, and use the terrain mode in ArcMap and ArcCatalog.

Loading surface feature data into a geodatabase

In this scenario, you have lidar points and photogrammetric breaklines stored in two separate ASCII text files. The data will be used to construct your terrain dataset. To accomplish this, you need to import these into feature classes that reside in a feature dataset. The terrain will be generated in the same location as the source data. You've been provided with a file geodatabase with a feature dataset. It contains two polygon feature classes: one for lidar, the other to delineate the study area. The initial step will be to import the two ASCII files into the feature dataset as feature classes. One feature class will delineate the photogrammetric breaklines, while the other feature class will contain the lidar points.

Steps:
1. Start ArcCatalog by clicking Start > All Programs > ArcGIS > ArcCatalog 10.

2. Click Customize > Extensions.
   The Extensions dialog box opens. Verify the 3D Analyst option is enabled. If it’s not, check it and close the dialog box.

3. Click Customize > Extensions.
   The Extensions dialog box opens. The 3D Analyst extension is enabled. Click OK to close the dialog box.

4. Open ArcMap.
Known Limits – Personal Geodatabase

- Not storage efficient
- Limited 2GB capacity
- Significant performance drop before capacity reached
- Not recommended for terrains over 20 million points
Known Limits – No Geographic Coordinates

- Terrain dataset use Delaunay triangulation
  - Method is valid only when data is projected
- Tools on user interface will prevent creation of terrains in feature datasets that use Angular Coordinate Systems
Best Practices

- LAS Over ASCII
- Use File or SDE GDB (Personal - 2GB Limit)
- Consider file or enterprise geodatabase for large datasets (> 1-2 billion points)
- Terrain dataset must be stored in a feature dataset
- Use projected coordinates
- Use Consistent Units (x, y, and z) and contiguous datasets
- Breakline enforcement
- Use ArcGIS for lidar derived rasters

Workflow to serve elevation:
Performance and Size Estimates

• Import:
  - 800 million LAS points per hour

• Terrain pyramid build:
  - 80 million points per hour using z-tolerance filter
  - 400 million points per hour using window size filter

• Storage:
  - 150 million points (geometry only) = 1GB
  - Terrain pyramid will be roughly same size as source multipoint feature class so total storage can double
    - Can use option to embed points to recover space

Timed using HP xw4400 Core2 Duo 2.67 GHz PC
Reads/writes using same drive
File Geodatabase
What’s Coming at ArcGIS 10.1

• New ArcGIS LAS dataset to support lidar directly
• Quickly view lidar data in 2D and in 3D
• Perform quality assurance checks on LAS files
• Update lidar class codes
Questions?

Please fill out the evaluation form.....

www.esri.com/sessionevals